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First fossil turtle from Hainan Island, China

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Abstract - Although Hainan Island is one of the richest regions for living turtle species in China, no fossil turtle had hitherto been discovered there. In this paper we report on a partial turtle shell from the Middle Pleistocene of Xinchong Cave, Changjing, Hainan, which is the first fossil turtle from that island. The specimen is identified as belonging to an extant geoemydid, *Mauremys sinensis*. This discovery indicates that the species, as a component of the extant turtle fauna in Hainan, had already reached the island by the Middle Pleistocene.

Keywords: *Mauremys sinensis*, Geoemydidae, cave deposits, Middle Pleistocene, Hainan Island.

1. Introduction

Hainan Island is one of the richest regions for living turtle species in China, with four non-marine turtle families (Geoemydidae, Testudinidae, Platysternidae and Trionychidae), altogether including no less than eleven species (Zhang *et al*., 1998; Shi *et al*., 2011; TTWG, 2012) (Fig. 1). None are endemic species; all of them are present on the Chinese mainland and adjacent domains. Due to geological and geographical factors, vertebrate fossils are extremely rare on Hainan Island; all of them are from Cenozoic cave deposits (Hao and Huang, 1998) and no fossil turtle had hitherto been recorded from there. Here we report on a turtle shell from the Middle Pleistocene of Hainan Island. It is assigned to the geoemydid *Mauremys sinensis* (Gray 1834). The discovery of a freshwater turtle on that island provides the information about the evolution of the turtle fauna of Hainan and new evidence about its paleogeography. The specimen is housed in the Culture and Sports Bureau of Changjiang Li Autonomous County.

Figure 1. Map showing the location of Changjiang City, Hainan Province, China.

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2. Geographical and geological setting

The specimen was collected from Xinchong Cave in 2006. Located some 20 km south of Changjiang city, Xinchong Cave is on the right bank of Nanyang Creek which is a tributary of the Changhua River. The cave is about 20 metres above the water surface. After the discovery of the cave in 1995 by a villager, excavations were carried out by the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences and local institutions in 2006. The fissure filling deposits of the cave have yielded a rich vertebrate fauna, including *Gigantopithecus* sp., *Stegodon* sp., *Rhinoceros sinensis*, *Crocuta ultima*, *Sus* sp., *Cervus* sp., rodents, reptiles, birds and fishes. Previously considered as Late Pleistocene in age, new dating by electron spin resonance (ESR) provides an age of 0.4 to 0.6 Ma (Middle Pleistocene), which represents the oldest vertebrate fauna of Hainan Island (Li *et al*., 2008).

3. Systematic paleontology

Order Testudines Batsch, 1788
Suborder Cryptodira Cope, 1868
Superfamily Testudinoidea Batsch, 1788
Family Geoemydidae Theobald, 1868
Genus *Mauremys* Gray 1869

Type Species *Mauremys leprosa* (Schweigger, 1812)

Diagnosis Carapace low arched and medially keeled; plastral buttresses moderately, developed along half way of the costal plate; femoro-anal sulcus running perpendicularly to the lateral edge of the plate; anal notch large; pygal wider than long.

Mauremys sinensis (Gray 1834)

Referred material

Posterior half of a shell (Museum of Changjiang Li Autonomous County No. HNCJBWG0098: 00098, Figure 2).

Locality

Xinchong Cave, Baoyou Village, Qicha Township, Changjiang Li Autonomous County, Hainan Province, China; Middle Pleistocene.

Diagnosis

This species differs from all other fossil and extant *Mauremys* species in the following combination of characters: carapace medially keeled, lateral keels disappear in adult; two suprapygals and one pygal; marginal scutes restricted to peripheral plates except the twelfth pair of marginals, the costoperipheral sutures very close to the pleuromarginal sulci especially at the sixth and seventh marginal scutes; sulcus between the twelfth marginal scutes crosses the suture between the second suprapygal and the pygal.

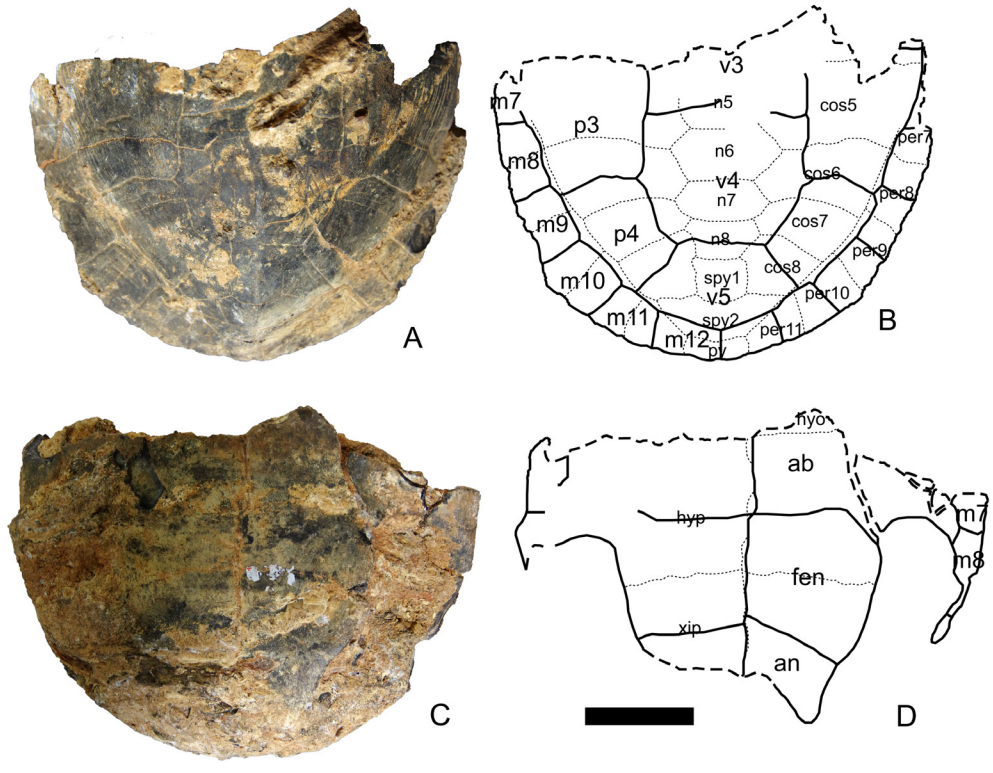

Figure 2. *Mauremys sinensis* (HNCJBWG0098: 00098) from the Middle Pleistocene Xinchong Cave, Hainan Island. A-B: carapace in dorsal view; C-D: plastron in ventral view. Scale bar: 50mm.

3.1. Description

The specimen consists of the posterior-half of a shell with articulated carapace and plastron, but without any limb bones. The cavity between the carapace and plastron is filled with semi-consolidated red soil. The preserved length of the specimen is 21.9 cm and the width is 14.6 cm. The total length of the carapace is estimated at about 30 cm. The shell is moderately domed, with a height of 11.8 cm. The carapace bears a midline keel, but lateral keels are absent. The posterior margin of the carapace is smooth, without serrations.

The preserved part of the carapace includes the fifth to eighth neurals, two suprapygals, one pygal, the fifth to eighth costals and the seventh to eleventh peripherals. All neurals are hexagonal, with short sides in front especially in the eighth neural, and their width being significantly greater than their length. The first suprapygal is roughly quadrilateral. The second suprapygal plate has a wide triangular shape, with the width more than three times its length and the posterior border strongly convex backwards. The pygal plate is wider than long and short, its width being more than twice its length. This plate is entirely restricted to the twelfth pair of marginal scutes, with its anterior border far posterior to the sulcus between the fifth vertebral scute and twelfth marginal scutes.

The scute sulci are well imprinted on the carapace. The third vertebral is incomplete. The length of the fourth vertebral is slightly greater than its width. The lateral sulci of this scute are slightly angled. The fifth vertebral scute is trapezoidal and wider than long. The third and fourth pleural scutes are narrower than the vertebral scutes. The medial edge of the marginals and the outer edge of the pleurals have parallel growth lines. The marginal scutes are restricted to the peripheral plates except the twelfth pair of marginals, so that the sulcus between the twelfth marginals crosses the suture between the second suprapygal and pygal.

The plastron is sutured to the carapace. The hypoplastra and xiphiplastra are preserved, as well as a small fragment of the left hyoplastron. The posterior lobe is wide, with convex lateral borders and a light constriction at the lateral end of the femoroanal sulcus. The inguinal buttress inserts at about half-way up the suture between the fifth and sixth costals. The xiphiplastra are broken, but they obviously have a wide anal notch. Most parts of abdominals, femorals, anals and inguinals are preserved, but the latter are hard to discern because of damage. The anal scutes are shorter than the femoral scutes. The hypop-xiphiplastral suture almost equally divides the femoral. The femoro-anal sulcus runs perpendicularly to the lateral edge of the xiphiplastron.

3.2. Comparisons

The shell from Xinchong Cave belongs to a testudinoid turtle because the inguinal buttress contacts the costal plates (Gaffney & Meylan, 1988). The general shell morphology, especially the suprapyal/pygal pattern allows its assignment to the family Geoemydidae. The arched shell, the large anal notch and the absence of inframarginals distinguish the Hainan specimen from the platysternid *Platysternon megacephalum*. It is also excluded from Testudinidae which have a high domed carapace and a longer pygal. In addition, the small first suprapygal followed by a very wide second suprapyal in the Hainan specimen is different from that of the testudinids, which have a single trapezoidal suprapygal (e. g. *Eurotestudo hermanni*), two suprapygals forming together a trapezoid (e. g. *Manouria impressa*), or a posteriorly bifurcated first suprapygal that bounds the second suprapygal (e. g. *Indotestudo*; Lapparent de Broin *et al*., 2006). Within Geoemydidae, the wide anal notch and absence of a hinge on the plastron in the shell from Xinchong Cave differ greatly from *Cuora* spp. Its large size and smooth peripheral free margins are distinct from the smaller shell with a strongly serrated posterior carapace margin of *Geoemyda spengleri*. *Sacalia quadriocellata* is smaller and its anal notch is shallower. The combination of features including a relatively low domed carapace, the presence of a midline keel, the absence of lateral keels, the femoro-anal sulcus running perpendicularly to the lateral edge of the xiphiplastron and a large anal notch as seen in our specimen agree with those of *Mauremys*.

Within the genus *Mauremys*, the Hainan specimen has a moderately arched shell as in *M. sinensis*, *M. mutica* and *M. annamensis*; while *M. caspica*, *M. leprosa*, *M. rivulatar* and *M. japonica* have a relatively low arched shell, and *M. nigricans* and *M. reevesii* have a relatively high arched shell. The widest point of the shell is at the midlength or slightly posterior to it in the Hainan specimen as in *M. sinensis*. The shell of *M. caspica*, *M. japonica*, *M. leprosa*, and *M. mutica* is widened posteriorly. All *Mauremys* have three keels in the young individuals, but adult *M. sinensis* only retains a midline keel, like *M. japonica*, *M. leprosa*, *M. mutica*, while *M. nigricans*. *M. annamensis*, *M. caspica*, *M. reevesii* and *M. rivulata* retain three keels in adults. As in *M. sinensis,* the shell from Hainan has the costoperipheral suture close to the pleuromarginal sulcus. It is why *M. sinensis* from the Anyang archeological site was incorrectly identified as *Testudo* (Ping, 1930; Bien, 1937). They are far distant from each other in *M. annamensis* and *M. mutica*; but very close, even coincident with one another, in *M. japonica*. Our specimen, like *M. sinensis* and most other *Mauremys*, has two suprapygals; while both *M. japonica* and *M. leprosa* have three suprapygals. As in *M. sinensis* as well as *M. japonica*, *M. leprosa*, and *M. mutica*, our specimen has the sulcus between the twelfth marginals crossing the suture between the second suprapygal and pygal. In other words, in these taxa the fifth vertebral scute meets the twelfth marginals on the second suprapygal. In contrast, the fifth vertebral meets the twelfth marginals on the pygal in *M. annamensis* and *M. reevesii*. In addition, the hypop-xiphiplastral suture is situated almost at the midlength of the femoral in our specimen as in *M. sinensis* and *M. japonica*. The comparisons between the species of *Mauremys* are summarized in Table 1. Based on the shell morphology, it appears that *M. sinensis* is closer to *M. japonica* than to other species of the genus.

Table 1. Comparison of shell characters within the genus *Mauremys*

	M. annamensis	*M. caspica*	*M. japonica*	*M. leprosa*	*M. mutica*	*M. nigricans*	*M. reevesii*	*M. rivulata*	*M. sinensis*
Shell shape: the widest point	At midlength	Posterior	Posterior	Posterior	Posterior	At midlength or slightly posterior	At midlength	At midlength or slightly posterior	At midlength or slightly posterior
Shell height	Moderate	Low	Low	Low	Moderate	High	High	Low	Moderate
Number of keels on adult carapace	3	3	1	1	1	1	3	3	1
Distance between costoperipheral suture andpleuromarginal sulcus	Far apart	?	Close, even coincident	Intermediate	Far apart	?	Intermediate	?	Close
Number of suprapygals	2	?	3	3	2	?	2	?	2
12^{th} marginal sulcus crosses 2nd suprapygal-pygal suture	No	?	Yes	Yes	Yes	?	No	?	Yes
Hypop-xiphiplastral suture position on the femoral	Slightly behind the midlength	?	At midlength	Slightly behind the midlength	Slightly behind the midlength	?	Slightly behind the midlength	?	At midlength

4. Discussion and conclusions

The shell from the Middle Pleistocene Xinchong Cave is referred to the geoemydid turtle *Mauremys sinensis*. Today the living *M. sinensis* has a wide geographical distribution on the Chinese mainland, being present in Fujian Province, Guangdong Province, Guangxi Zhuang Autonomous Region, Hainan Province, Jiangxi Province, and also on Taiwan Island. It is also present in Laos and Vietnam. Fossils and subfossils of this species have been reported from the Yin Dynasty Anyang site, Henan Province (Ping, 1930), the Pliocene of Shanxi Province (Yeh, 1963), and the Pleistocene of Penghu strait of Taiwan region (Tao, 1988). In the past, Hainan Island was episodically connected to the continent (Yan, 2006). The discovery of *M. sinensis* in the Middle Pleistocene of Hainan Island indicates that the species had already reached the island by that time. The presence of a freshwater turtle with a continental origin on Hainan provides additional evidence that the island was once connected to the continent, as suggested by the land mammal fauna present in Xinchong Cave, including *Gigantopithecus* (Li *et al*., 2008).

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